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(54) Title: PACKET-BASED MOBILE NETWORK

(57) Abstract: A telecommunications system uses a packet switched network to provide communications capabilities to mobile devices. Base transceiver stations (BTSs) on the network communicate with mobile devices in their respective coverage areas. User media exchanged between the mobile devices and the BTSs are encoded in the mobile devices' native formats. The BTSs encapsulate the user media in a packet-based representation and send it to the other endpoint of the session via the network. A media gateway interfaces with telephone networks and converts media between the native formats of the mobile devices and the native formats of the telephone networks. A softswitch provides session processing and media connection signaling and switching via control signals encoded in a packet-based representation and sent to the BTSs and/or media gateways via the packet switched network.

**PACKET-BASED MOBILE NETWORK****INVENTORS****JACK K. MAR****STEPHEN J. WILLIAMS****BRADLEY LONG****RONALD B. MCLEOD****CROSS-REFERENCE TO RELATED APPLICATIONS**

- 10 **[0001]** This application claims the benefit of U.S. Provisional Application No. 60/364,707, filed March 14, 2002, and incorporated herein by reference. This application is related to U.S. Utility Application No. 10/172,576, filed June 13, 2002, and incorporated herein by reference.

**BACKGROUND OF THE INVENTION****FIELD OF THE INVENTION**

- 15 **[0002]** This invention pertains in general to communication networks and in particular to communication networks for supporting mobile devices, such as cellular telephones.

**BACKGROUND ART**

- 20 **[0003]** Cellular telephones and other mobile devices having wireless communications capabilities are ubiquitous in the modern world. Users expect the mobile devices to work everywhere at any time. Wireless networking providers, such as cellular telephone service providers, built extensive wireless networks in order to meet the users' expectations.

- 25 **[0004]** Nevertheless, existing wireless networks oftentimes do not meet the users' expectations or the networking providers' goals. Coverage is often spotty, especially indoors or in hilly areas. While the obvious solution to this problem is to provide more coverage by installing additional base stations, this solution can be expensive. In addition to the base stations, the provider will need to install back-end hardware such as controllers, switches, and trunks in order to control the base stations and support the increased network capacity.

- 30 **[0005]** Moreover, wireless networks have nearly reached their capacity limits in many metropolitan areas. As a result, users occasionally have problems obtaining service in crowded

areas or during peak times. For example, it can be difficult to obtain service in stadiums, concert halls, and other venues where large crowds of potential mobile device users congregate.

5 [0006] There are also challenges in providing viable network coverage in rural, low-density areas. Generally, many remote base stations are needed to serve a large geographical area. Yet, if the area is low density, the coverage provider typically uses only a single mobile switching center (MSC) and base station controller (BSC) to support the network. This architecture means that high-cost, long-distance trunks are needed to connect the remote base stations with the centralized MSC and BSC, often leading to high operating costs. The problems inherent in providing coverage to rural areas are greatly compounded when satellite circuits are used to provide inter-machine or public switched telephone network (PSTN) trunks. Satellite bandwidth is very expensive and must be conserved if the wireless network is to be profitable.

15 [0007] Thus, there is a need for a flexible wireless networking system and architecture that can provide cost-effective coverage to mobile devices in both dense urban and sparse rural areas. Preferably, a solution meeting this need will allow networking providers to add extra wireless networking capacity to fill in coverage gaps and/or meet the demands of high-traffic areas without incurring the costs normally inherent in extending the network. The solution will also preferably conserve satellite bandwidth, as well as reduce the operating costs incurred due to operating the MSCs and BSCs.

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#### BRIEF SUMMARY OF THE INVENTION

[0008] The above need is met by a telecommunications system that uses a packet switched network to provide communications capabilities to mobile devices. The packet switched network, often referred to herein as the Internet protocol (IP)-based network because IP is a common packet-based protocol, allows the resources utilized to provide the communications capabilities to be distributed and shared in an efficient manner.

25 [0009] In one embodiment, multiple base transceiver stations (BTSs) are connected to the IP network. Each BTS communicates with mobile devices in its respective coverage area via an air interface. The encoding of the user media carried on the air interface depends upon the communications technology utilized by the mobile devices and BTSs. For example, the mobile devices and BTSs can utilize Code Division Multiple Access (CDMA) and/or Global System for Mobile Communications (GSM) technology. Depending on the communications technology, the user media can be encoded using enhanced variable rate coding (EVRC),

QualComm excited linear predictive (QCELP) coding, full rate (FR) coding, enhanced FR (EFR) coding, etc.

5 [0010] When a BTS receives user media from a mobile device, such as during a voice telephone call or other user media session, the BTS encapsulates the user media in an IP-based representation and routes it over the IP network to the other endpoint of the session. Other types of user media sessions include text messages and multimedia messages in the form of a picture or streaming media. The BTS allows the user media to be transmitted over the IP network while preserving the mobile device's native encoding of the user media. Likewise, when the BTS receives encapsulated user media from the IP network, the BTS removes the encapsulation to yield user media in the native format of the mobile device. The BTS sends the  
10 natively-encoded media to the mobile device.

[0011] A softswitch on the IP network controls the operation of the BTSs, mobile devices, and other entities in the telecommunications system. The softswitch provides session processing and controls media connection switching and signaling for the mobile devices. The  
15 softswitch also provides mobility management for the mobile devices. Preferably, the softswitch provides this functionality by encoding control signals for non-packet switched communications protocols and interfaces in IP-based representations and sending the signals to the BTSs, mobile devices, and the media gateway via the IP network.

[0012] A media gateway on the IP network preferably interfaces with telephone networks such as the public land mobile network (PLMN) and the public switched telephone network (PSTN) and operates under the control of the softswitch. For sessions between a mobile device on the system and a device on one of the telephone networks, the media gateway receives the encapsulated user media from the BTS and removes the encapsulation to obtain the natively-encoded user media. The media gateway converts the user media into the native encoding of  
20 the telephone network, if necessary, and sends the user media over the telephone network. Similarly, the media gateway receives user media from the telephone network, converts and encapsulates the media, and sends it to the appropriate BTS for the mobile device via the IP network.

[0013] The present invention extends the core network to the access and transit network edge. The MSC and base station subsystem (BSS) functionalities are distributed over the packet-based network. Signaling, control, media, and system management among the  
30 softswitch elements, resource media gateway, PSTN/PLMN media gateway, and radio access

media gateway (such as at the BSS) are directly connected by packet-based transport. Functions such as transcoding that were traditionally done by the BSC, are instead routed in native codec format from the radio access media gateway over the packet-based network and transcoded only if the media encoding format conversion is required or desired. Since the control signals are

5 low bandwidth signals, the softswitch can be located on a relatively low-bandwidth network link yet still control many BTSs. Voice and data media packets can be optimally routed such as on the shortest path without backhauling and centrally switching the media as is done in traditional MSC solutions. The media gateway can be located at a network connection point where it can interface with the PLMN and/or PSTN. Moreover, the present invention reduces

10 the costs associated with the BTSs by providing functionality for converting between different encodings of the user media at the shared media gateway.

#### BRIEF DESCRIPTION OF THE DRAWINGS

- 15 [0014] FIG. 1 is a high-level block diagram illustrating a telecommunications system according to an embodiment of the present invention;
- [0015] FIG. 2 is a high-level block diagram illustrating a portion of the telecommunications system of FIG. 1 from a functional perspective;
- [0016] FIG. 3 is a block diagram illustrating the communications protocol stack in one embodiment of the air interface through which the radio and mobile device communicate;
- 20 [0017] FIG. 4 illustrates the protocol stack for carrying user media on the pathway between the network endpoint control module in the base transceiver station (BTS) and the corresponding module in the media gateway according to an embodiment of the telecommunications system;
- 25 [0018] FIGS. 5A-C illustrate protocol stacks for carrying control signals on the pathway between the mobility management module of the softswitch and the signaling management module of the BTS according to several embodiments of the telecommunications system;
- [0019] FIGS. 6A-B illustrate protocol stacks for carrying control signals on the pathways among the media control modules of the BTSs and the media gateway and according to embodiments of the telecommunications system; and

[0020] FIG. 7 is a high-level block diagram illustrating entities of the telecommunications system of FIG. 1 and illustrating examples of media flow paths through the system.

[0021] The figures depict an embodiment of the present invention for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles of the invention described herein.

#### DETAILED DESCRIPTION OF THE INVENTION

[0022] FIG. 1 is a high-level block diagram illustrating a telecommunications system 100 according to an embodiment of the present invention. Like elements are identified with like reference numerals. A letter after the reference numeral, such as "112A," indicates that the text refers specifically to the element having that particular reference numeral. A reference numeral in the text without a following letter, such as "112," refers to any or all of the elements in the figures bearing that reference number (e.g. "112" in the text refers to reference numerals "112A" and/or "112B" in the figures).

[0023] FIG. 1 illustrates a packet switched network 110 in communication with multiple entities, including base station transceivers (BTSs) 112, a softswitch (SS) 128, a signaling gateway 130, a media gateway 132, a voice over Internet protocol (VoIP) device 134, a data service serving node (DSN) 118, and an operations and maintenance console (OMC) 120. Each BTS 112 is illustrated as being in communication with two mobile devices 114. The signaling gateway 130 and media gateway 132 are each in communication with a public switched telephone network (PSTN) 122 and a public land mobile network (PLMN) 124. The DSN 118 is in communication with an external data service network 126.

[0024] The system 100 of FIG. 1 enables the entities on the network 110 to use non-packet based communications interfaces and protocols to communicate over the packet switched network 110 and support telecommunications on the mobile devices 114. The use of the packet switched network 110 allows the entities on the network 110, and the functionality provided by the system 100, to be distributed in an efficient and cost effective manner. In one embodiment, the system 100 separates the media functionality and feature provisioning from the control functionality. Certain control elements for the system 100, which are typically implemented in software, are preferably located at or near the BTSs 112. In contrast, control elements that can be shared and/or centralized are preferably located at a centralized location, such as at the SS

128. Media elements which are typically implemented with hardware, such as digital signal processing (DSP), are preferably located at the media gateway 132. This design reduces the expenses associated with the BTSs 112 and achieves overall efficiencies by allowing the relatively inexpensive BTSs 112 to be distributed throughout the geographic areas desiring coverage and the more expensive components at the SS 128 and/or media gateway 132 to be shared. Embodiments of the system 100 can distribute the entities and/or the functionality of the entities in a different manner than described herein.

[0025] Turning now to the individual entities illustrated in FIG. 1, the network 110 preferably uses conventional networking technologies, such as Ethernet and asynchronous transfer mode (ATM)-based circuits, to route packet-based data. A preferred embodiment of the network 110 uses the IP and its attendant protocols, such as the transmission control protocol (TCP), the user datagram protocol (UDP), or the stream control transport protocol (SCTP) to route data packets. For this reason, the network 110 is often referred to herein as the "IP network." Other embodiments of the system can use other protocols to carry and/or route the data. In one embodiment, the IP network 110 is dedicated to providing the functionality described herein. In another embodiment, all or part of the network 110 utilizes shared links such as links over the Internet or other publicly-accessible data networks or shared links provided by a communications services provider.

[0026] In one embodiment, the links of the IP network 110 are secure to prevent eavesdropping. The security can be provided by making the links physically-resistant to eavesdropping and/or encrypting the data carried on the links. In one embodiment, the entities on the network 110 use conventional security technology, such as the secure sockets layer (SSL) and/or virtual private networks (VPNs) using Internet Security Protocol (IPSec) tunneling, to secure the data sent over the network 110.

[0027] Preferably, the IP network 110 includes quality of service (QoS) functionality in order to provide predictable throughput during periods of network congestion. More specifically, the QoS functionality allows the network 110 to guarantee that the entities on the network related to the telecommunications system (e.g., the BTSs 112) will receive at least a specified minimum bandwidth even when the network is otherwise congested. The IP network 110 may also lack QoS functionality. In this case, it is preferable, but not necessary, to "overbuild" the network 110 to reduce the chance of network congestion.

**[0028]** FIG. 1 illustrates four BTSs 112 coupled to the network 110. Although only four BTSs 112 are shown in FIG. 1, embodiments of the system 100 can have hundreds or thousands of BTSs in communication with network 110. Each BTS 112 serves a geographic region, or "cell," and is capable of communication with wireless-enabled mobile devices 114 in the region.  
5 In addition, each BTS 112 is preferably configured to communicate over the IP network 110.

**[0029]** The BTSs 112 preferably use radio frequency (RF)-based communications technologies to communicate with the mobile devices 114 or fixed wireless terminals. In other embodiments, one or more of the BTSs may support additional wireless communications technologies, such as infra-red. Multiple BTSs 112 may be used in proximity with each other to  
10 provide uniform communications coverage for an area.

**[0030]** In a preferred embodiment, the BTSs 112 communicate with cellular telephones and other suitably-enabled mobile devices 114 in their respective coverage areas. The BTSs 112 allow voice and/or data (individually and collectively referred to as "user media") to be communicated among the mobile devices 114 and other devices on the network 110, and, by  
15 extension, devices on the PSTN 122, PLMN 124, and/or external data service network 126.

**[0031]** These communications of user media among the devices are organized into "sessions." An example of a session is a voice telephone call. Other examples of sessions include video calls, fax calls, dialup connections to a server, a connection established for purposes of telemetry or telepresents, chat communications, etc.

20 **[0032]** A session exists between two or more "endpoints." As used herein, the term "endpoint" broadly refers to an entity through which user media are routed during a session. For example, the BTSs 112 and media gateway 132 are possible endpoints for sessions. The term "endpoint" can also refer to an addressable interface on the entity through which the user media are routed. For example, each BTS 112, media gateway 132, or other entity on the IP  
25 network 110 typically has a number of individually-addressable endpoints. These endpoints allow the system 100 to keep track of multiple sessions routed through the same entity.

**[0033]** Depending upon the embodiment, the mobile devices 114 and BTSs 112 communicate user media via one or more different communications technologies including Code Division Multiple Access (CDMA), Global System for Mobile Communications (GSM),  
30 Universal Mobile Telecommunications System (UMTS), 802.11, and/or Bluetooth. Depending on the communications technology, the user media representing voice can be encoded with



enhanced variable rate coding (EVRC), Qualcomm excited linear predictive (QCELP) coding, full rate (FR) coding, enhanced FR (EFR) coding, voice over IP (VoIP) coding, adaptive multi-rate (AMR) coding, etc. The mobile devices 114 and BTSs 112 can also preferably exchange user media representing data via the wireless application protocol (WAP), short message service (SMS) protocol, multimedia messaging service (MMS) protocol, and/or TCP/IP.

[0034] The BTSs 112 preferably encapsulate user media received from the mobile devices 114 in an IP-based representation suitable for transport across the IP network 110. The native format of the user media is preserved, but the user media are encapsulated in an encoding that functions with the IP. Likewise, the BTSs 112 preferably remove the encapsulation from user media received from the IP network 110. The encapsulated user media are preferably carried on the IP network 110 according to a real-time streaming protocol.

[0035] FIG. 1 shows two mobile devices 114 in communication with each BTS 112 even though any given BTS is typically in simultaneous communication with many mobile devices and mobile devices may be in communication with multiple BTSs. As used herein, the term “mobile device” covers all devices that may be in communication with the BTSs 112, regardless of whether a particular device is typically or actually “mobile.” In addition to cellular telephones, mobile devices 114 may include personal digital assistants (PDAs), laptop or desktop computers having modules for supporting wireless telecommunications, etc. In one embodiment, the functionality of the BTS 112 and mobile device 114 is incorporated into one device.

[0036] Each mobile device 114 is preferably associated with at least one “subscriber.” Each subscriber, in turn, is associated with a particular communication provider such as a nationwide cellular telephone service provider. As used herein, the term “subscriber” merely refers to the person and/or entity associated with a mobile device and does not imply that there is an actual subscription in place.

[0037] The VoIP device 134 is a wired or wireless communications device that directly interfaces with the IP network 110. In one embodiment, the VoIP device 134 is a special purpose telephone containing DSP functionality for encoding signals representative of voice or other audio into the VoIP representation and vice versa. In another embodiment, the VoIP device 134 includes a standard telephone coupled to an Internet access device (IAD). The IAD is connected between the telephone and the IP network 110 and converts audio signals between the representation utilized by the telephone and the VoIP. The SS 128 preferably controls the

VoIP device 134 via control signals carried over the IP network 110 to provide standard telephone functionality.

5 [0038] The PSTN 122 is the conventional telephone network. User media on the PSTN 122 are typically encoded using pulse code modulation (PCM). The PLMN 124 is preferably a cellular telephone network operated by a cellular telephone service provider, such as AT&T, SPRINT, CINGULAR, etc. User media on the PLMN 124 are typically encoded using a native format of the mobile devices supported by the network, such as EVRC, QCELP, FR, EFR, VoIP, AMR, etc.

10 [0039] The DSN 118 supports and provides communications between servers on the external data service network 126 and the mobile devices 114 and/or other entities on the IP network 110 by routing data to the appropriate inbound/outbound locations. In one embodiment, the external network 126 is representative of the Internet at-large and the DSN 118 serves as the peering point between the IP network 110 and the Internet. In another embodiment, the external network 126 is a private and/or public network other than the Internet.

15 Embodiments of the telecommunications system 100 can have multiple DSNs 118 connecting the IP network 110 to multiple other networks. The communications supported by the DSN 118 preferably enable WAP, SMS, MMS, and other web-enabled features on the mobile devices 114, as well as enabling general IP-based communication between the two networks.

[0040] The particular hardware and/or functionality provided by the DSN 118 depends upon the technology utilized by the mobile devices 114. If the mobile devices 114 utilize CDMA, the DSN 118 preferably includes a packet data serving node (PDSN). Similarly, if the mobile devices 114 utilize GSM or UMTS, the DSN 316 preferably includes a serving general packet radio service (GPRS) support node (SGSN).

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[0041] The SS 128 preferably controls the operation of the BTS 112 and other devices on the IP network 110. In one embodiment, the SS 128 is formed of one or more modules executing on a computer system. As used herein, the term "module" refers to computer program logic and/or any hardware or circuitry utilized to provide the functionality attributed to the module. Thus, a module can be implemented in hardware, firmware, and/or software.

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[0042] The SS 128 preferably provides session processing and controls media connection switching and signaling for the mobile devices 114 and any VoIP devices 134. The SS 128 also preferably provides mobility management for the mobile devices 114. The mobility

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management enables roaming capabilities. That is, mobility management allows the mobile devices to receive service as they move among the coverage areas provided by the BTSs 112 on the IP network 110 and external coverage areas (e.g., other coverage areas on the PLMN 124). The SS 128 preferably provides mobility management by supporting or interfacing to an external home location register (HLR) access functionality (or, in the case of UMTS networks, home subscriber server (HSS) access functionality). A HLR is a storage location that holds information about a given subscriber that the SS 128 and devices on the PLMN 124 use to authorize and provide services to the subscriber. Preferably, information for any given subscriber is kept in only one HLR. The SS 128 and devices on the PLMN 124 use either the IS-41 internetworking standards or GSM MAP to access the HLR.

[0043] In one embodiment, the SS 128 maintains a HLR for at least some of the subscribers associated with the mobile devices 114 and makes the HLR accessible to the PLMN 124. In this or another embodiment, the HLRs for at least some of the subscribers utilizing mobile devices 114 in communication with the BTSs 112 are maintained on the PLMN 124 by a cellular telephone service provider and the SS 128 accesses the HLRs to authorize and provide services to the subscribers in the coverage areas provided by the BTSs 112 on the IP network 110.

[0044] The mobility management capabilities of the SS 128 allow it to control the subscribers' access to the local and external coverage areas. For example, the SS 128 can grant or deny service to a mobile device within the local coverage area provided by the BTSs 112 on the IP network 110. Similarly, the SS 128 can control whether a mobile device 114 associated with a subscriber having an account maintained by the SS 128 is allowed to obtain service on the PLMN network.

[0045] The mobility management capabilities of the SS 128 also include handoff (referred to as "handover" in GSM terminology). "Handoff" is the ability to keep an active session connected and functioning when a mobile device 114 on the session moves among the coverage areas provided by the BTSs 112 on the IP network 110 or other networks (e.g., the PLMN 124). The SS 128 also preferably uses its mobility management capabilities to enable location-based services to the mobile devices 114. In sum, the mobility management capabilities of the SS 128 generally allow a subscriber to use a mobile device 114 in the normal manner.

[0046] In one embodiment, the signaling gateway 130 is also formed of one or more modules executing on a computer system. The signaling gateway 130 is preferably in

communication with the IP network 110, the PSTN 122, and the PLMN 124 and operates in response to commands from the SS 128. The signaling gateway 130 performs media connection signaling to support sessions among the mobile devices 114 in communication with the BTSs 112, VoIP devices 134, and devices on the PSTN 122 and PLMN 124. The signaling gateway 5 130 also preferably handles signaling for providing mobility management for the mobile devices 114.

[0047] In one embodiment, the media gateway 132 is likewise formed of one or more modules executing on a computer system. The media gateway 132 is preferably in communication with the IP network 110, the PSTN 122, and/or the PLMN 124 and serves as a gateway between the telephone networks and the IP network. The media gateway 132 converts 10 user media (e.g., voice data) among the encodings utilized by the mobile devices 114, PSTN 122, PLMN 124, and VoIP devices 134. The media gateway 132 also adds and removes the IP encapsulation of user media sent and received via the IP network 110. The native formats of the mobile devices can be EVRC, QCELP coding, FR coding, EFR coding, VoIP coding, AMR 15 coding, etc. The PLMN 124 typically uses these formats at the edge of the network, but converts the user media into PCM coding for internal transport. The PSTN 122 typically utilizes PCM coding.

[0048] The SS 128, signaling gateway 130, and media gateway 132 are preferably distributed on the network 110 at locations that are effective and efficient given the particular 20 embodiment. Preferably, the SS 128 is placed at a location chosen for its operational characteristics. For example, the SS 128 may be located on a link near a particular set of BTSs 112. The media gateway 132 is preferably placed at a location where it can efficiently interface with the PSTN 122 and/or PLMN 124. Embodiments of the system 100 can have multiple SSs 128, media gateways 132, and/or SGs 130 distributed on the network 110.

25 [0049] The OMC 120 is used by an administrator to interface with the BTSs 112, SS 128, signaling gateway 130, media gateway 132, DSN 118, and other entities on the IP network 110 to control and supervise the system. The OMC 120 is the logical equivalent of a control console for the devices and allows the administrator to specify and control available features, create and maintain subscriber profiles, configure the devices, review usage and billing records, perform 30 maintenance, etc. The OMC 120 may also store copies of subscriber profiles that are used to synchronize with the HLR for mobility purposes. The subscriber profiles preferably contain information identifying the subscribers, identifying the enterprises with which the subscribers

are associated, and describing the applications and features (i.e., rights and privileges) available to the subscribers.

[0050] FIG. 2 is a high-level block diagram illustrating a portion of the telecommunications system 100 of FIG. 1 from a functional perspective. FIG. 2 illustrates a wireless mobile device 114 and a BTS 112. The BTS 112 is in communication with the SS 128 and the media gateway 132. Arrows between the modules 202, 204, 206 represent the communication pathways formed over the IP network 110. In one embodiment, paths 202 and 204 carry control signals while path 206 carries user media. The media gateway 132 is in communication with the PLMN and/or PSTN (individually and collectively referred to herein as the "telephone network 212").

[0051] The mobile device 114 preferably communicates with the BTS 112 via an air interface 210. The BTS 112 contains numerous functional modules for communicating with, and providing services to, the mobile device 114 via this interface. A radio module 214 provides the RF communications capabilities between the mobile device 114 and the BTS 112. The radio 214 preferably provides traffic channel capabilities to enable it to effectively communicate with a variety of mobile devices 114. A broadcast control module 216 controls the operation of the radio 214. This module 216 maintains the radio 214 in a ready state in order to provide access to the mobile devices 114 within range. The broadcast control module 216 preferably uses the radio 214 to keep a control/access channel available and transmitting. Mobile devices 114 can camp on the control/access channel in order to receive pages (i.e., in order to receive notifications from the BTS 112). The broadcast control module 216 also broadcasts parameters that allow the mobile devices 114 to access the communications network and broadcast services available through the BTS 112.

[0052] A signaling management module 218 interfaces with the radio 214 and a mobility management module 228 in the SS 128 via communications path 202 and controls the mobile messaging at the BTS 112. The signaling management module 218 maintains session context so that the correct mobile device 114 gets the messages intended for it. The signaling management module 218 also performs the message handling aspects involved in mobility management and session processing.

[0053] A media control module 220 in the BTS 112 interfaces with media control module 232 in the SS 128 via pathway 204 and provides connectivity across the IP network 110 as determined or required by session processing. Once session processing determines that a

connection path is required, the media control modules 220, 232, 234 in the BTS 112, SS 128, and media gateway 132 create the logical connection across the IP network 110 by causing the data packets to be routed to the appropriate destinations. Thus, the operation of the media control module 220 is similar to traditional switching in that it creates, maintains, and releases communications paths in the communications system 100, except that the paths are logical paths over a packet-switched network.

**[0054]** A channel control module 222 provides the dedicated resources that are allocated to a mobile device 114 for a particular session. In one embodiment, each mobile device 114 that is active (e.g., in a voice call and/or another session) is assigned a separate traffic channel to use to transmit its media to/from the network for the session. In an embodiment using GSM, the channel control module 222 will provide the mobile device 114 with a time-division multiplexed (TDM) "time slot" for media transport over the air interface 210. In an embodiment using CDMA, the channel control module 222 will provide the "code" that constitutes the channel that the mobile device 114 uses for media transport. The channel control module 222 supervises and controls the mobile device 114 on the channel, as well as maintains basic radio channel functions. Preferably, the signaling management module 218 controls the operation of the channel control module 222.

**[0055]** A network endpoint control module 224 in the BTS 112 serves to control the individually-addressable endpoint interfaces at the BTS 112 through which user media are sent and received. The network endpoint control module 224 in the BTS 112 also preferably encapsulates the native user media in a format suitable for transmission via the IP network 110 (if necessary and/or desired). Likewise, when receiving user media from the network 110, the network endpoint control module 224 preferably decodes the user media into the native format of the mobile device 114 to which the media are destined (if necessary and/or desired). Path 206 represents a communication pathway for carrying user media between the media gateway 132 and the BTS 112.

**[0056]** Turning now to the SS 128, a feature control module 226 interacts with the mobility management module 228 and a session processing module 230 to provide enhanced calling features to the mobile devices 114. The enhanced calling features may include, for example, partial-number dialing, toll calling, call forwarding and transferring, conference calling, line camping, customized treatment depending upon the calling or called party, customized billing applications providing specialized billing reports, number portability, enhanced 911, concurrent

and sequential ringing, etc. The enhanced calling features may also include non-call associated features, such as following and/or location-based services. Embodiments of the feature control module 226 can provide different enhanced calling features instead of, or in addition to, the ones listed here.

- 5   **[0057]**   The mobility management module 228 interacts with the feature control 226 and session processing 230 modules to provide functionality for managing and providing service to the mobile devices 114. In general, the mobility management module 228 deals with issues related to the movement of the mobile devices 114. As such, the mobility management module 228 preferably supports features such as session roaming, session delivery, and handoff. The  
10   module 228 also preferably supports functionality addressing specialized features for wireless devices, such as functionality supporting privacy and authentication. In addition, the mobility management module 228 provides functionality supporting the wireless protocols utilized for the air interface 210 between the mobile device 114 and the radio 214.

- 15   **[0058]**   The session processing module 230 includes functionality for setting up, tearing down, and accounting for sessions across the IP network 110 and, if necessary, other networks. The module 230 also supports traditional switching capabilities including alternate routing, network signaling, timing distribution, translation, traffic measurements and controls, etc. via the IP network 110. The media control module 232 in the SS 128 preferably interacts with the media control modules 220, 234 in the BTS 112 and media gateway 132 to provide connectivity  
20   across the IP network 110.

**[0059]**   The media control module 234 in the media gateway 132 also interacts with the corresponding module in the SS 128 to provide connectivity. In addition, a network endpoint control module 236 in the media gateway 132 interacts with the corresponding module 224 in the BTS 112 to send and receive encapsulated user media via the IP network 110.

- 25   **[0060]**   A network interface module 238 in the media gateway 132 preferably interfaces with the telephone network 212. As such, this module 238 is adapted to convert user media between the encoding utilized by the telecommunications system 100 and the encoding utilized by the telephone network 212. The network interface module 238 also preferably performs signaling for either inband or common channel protocols in order to support session setup between the  
30   telecommunications system 100 and systems on the telephone network 212. A digital signal processing (DSP) module 240 preferably interfaces with the network endpoint control module

236 and the network interface 238. The DSP module 240 supports the user media conversion functionality of the network interface module 238.

[0061] FIG. 3 is a block diagram illustrating the communications protocol stack in one embodiment of the air interface 210 through which the radio 214 and mobile device 114 communicate. The top layer of the air interface 214, the data layer 310, transports user media packets generated by the mobile device 114 and received by the BTS 112 or vice-versa. The user media packets are preferably coded in the native format of the mobile device 114.

[0062] The next two layers are the link access control (LAC) layer 312 and the media access control (MAC) layer 314. The LAC layer 312 governs the assembling of data into frames and the exchanging of data between data stations. The MAC layer 314, in turn, supports topology dependent functions. The airlink layer 316 is the physical layer of the air interface 210 and, in this case, is the RF carrier and respective modulation for the communications between the mobile device 114 and radio 214.

[0063] FIG. 4 illustrates the protocol stack for carrying user media on the pathway 206 between the network endpoint control module 224 in the BTS 112 and the endpoint control module 236 in the media gateway 132 according to an embodiment of the telecommunications system 100. The top layer of the stack is the data layer 410. This layer preferably carries user media encoded in the native format of the mobile device 114. In one embodiment, the mobile device 114 supports the GSM communications technology and the data layer 410 carries data encoded according to FR and/or EFR coding. In another embodiment, the mobile device 114 supports the CDMA communications technology and the data layer 410 carries data encoded according to EVRC and/or QCELP. Other embodiments can support other coding schemes.

[0064] The natively-encoded user media are preferably encapsulated in a real-time protocol (RTP) (or other streaming protocol) layer 412. The RTP provides a transport mechanism for moving the time-sensitive user media across the IP network. To this end, the RTP layer 412 enables functionality such as detecting packet loss and compensating for any delay jitter. The RTP layer 412 also supports QoS functionality.

[0065] A UDP layer 414 provides functionality for distinguishing different communications sessions (such as port numbers) and provides a checksum functionality for verifying that user media arrives at the destination intact. The UDP layer 414 preferably runs on top of the IP layer 416. The IP layer 416 provides functionality for routing data packets over the network 110.



[0066] FIGS. 5A-C illustrate protocol stacks for carrying control signals over the pathway 202 between the mobility management module 228 of the SS 128 and the signaling management module 218 of the BTS 112 according to several embodiments of the telecommunications system 100. FIGS. 5A-C respectively illustrate different embodiments of the protocol stack. The embodiments are functionally equivalent, and different embodiments of the telecommunications system 100 can use any one of the described stacks (or multiple ones).

[0067] The top layer of the stack of FIG. 5A (and the other stacks) is the communications interface 510A. This interface carries messages for providing session control and mobility management to the BTSs 112, and to the mobile devices 114 via the BTSs. In embodiments of the system 100 supporting GSM mobile devices 114, the interface 510A is preferably the GSM-A interface. In embodiments of the system 100 supporting CDMA mobile devices 114, the interface 510A is preferably the Telecommunications Industry Association (TIA) interim standard IS-634 interface.

[0068] The next layer of the stack is the Signaling Connection Control Part (SCCP) layer 512A. This layer 512A contains messages that control signaling for connectionless and connection-oriented network services and address translation services. The SCCP layer 512A rests on a message transport part 3 (MTP3) layer 514A which provides functions and procedures related to message routing and network management. The MTP2-User Adaptation (M2UA) layer 516A is below the MTP3 layer 514 and provides a protocol for transport of MTP3 signaling messages over the IP network 110.

[0069] An SCTP layer 518A provides reliable transmission characteristics for the non-packet-based protocols being signaled across the IP network 110. The IP 520A layer provides the same functionality as the corresponding layer described with respect to FIG. 4.

[0070] The stack of FIG. 5B also has a communications interface as the top layer 510B. This layer 510B preferably provides the same functionality as the corresponding layer 510A in FIG. 5A. The next layer of the stack is the SCCP-LITE layer 512B. The SCCP-LITE layer 512B implements the SCCP-LITE protocol available from TELOS Technology, Inc. This protocol supports a subset of SCCP functionality and is specifically optimized for use on TCP/IP packet-based networks. Accordingly, the next two layers in the stack are the TCP 514B and IP layers 516B. The TCP layer 514B manages the dividing and reassembling of data into packets that are transported over the IP network 110 by the IP layer 516B.

[0071] The top layer 510C of the stack of FIG. 5C is a communications interface having the same functionality as corresponding layers 510A and 510B described above. In FIG. 5C, the layer 512C below the interface 510C is the SCCP User Adaptation (SUA) layer 512C. The SUA layer 512C supports the transport of SCCP user signaling over the IP using SCTP services. Accordingly, the Sctp layer 514C is below the SUA layer 512C and provides transport layer functions. The IP layer 516C provides the same functionality as the previously-discussed IP layers 522A, 516B.

[0072] FIG. 6A illustrates a protocol stack for carrying control signals on the pathways 204 among the media control modules 220, 232, 234 of the BTS 112, SS 128, and media gateway 132 according to an embodiment of the telecommunications system 100. The top layer 610A of the stack is the Media Gateway Control Protocol (MGCP), H.248/Megaco, or a similar such media control protocol. These protocols are utilized to set up, maintain, and terminate media connections between multiple endpoints, as well as to play tones or announcements to endpoints. Preferably, the next two layers of the stack are for UDP 612A and IP 614A, respectively. These layers facilitate the transport and routing of MGCP or H.248 messages over the IP network 110.

[0073] FIG. 6B illustrates a protocol stack for carrying control signals on the pathways 204 among the media control modules 220, 232, 234 of the BTS 112, SS 128, and media gateway 132 according to another embodiment of the telecommunications system 100. The top layer 610B of the stack is the Media Gateway Control Protocol (MGCP), H.248/Megaco, or a similar such media control protocol. These protocols are utilized to set up, maintain, and terminate media connections between multiple endpoints, as well as to play tones or announcements to endpoints. Preferably, the next two layers of the stack are for Sctp 612B and IP 614B, respectively. These layers facilitate the transport and routing of MGCP or H.248 messages over the IP network 110.

[0074] FIG. 7 is a high-level block diagram illustrating entities of the telecommunications system of FIG. 1 and illustrating examples of media flow paths through the system. FIG. 7 illustrates two mobile devices 114A, 114B each respectively communicating with a BTS 112A, 112B. The BTSs 112 communicate with the media gateway 132 via the IP network 110.

[0075] The mobile devices 114 communicate with their respective BTSs 112 via the air interface 210. The media flow path for the air interface 210 is identified with reference numeral

710. As described above, the user media on this portion of the path 710 are encoded according to the native format of the mobile device 114, such as FR, EFR, EVRC or QCELP.

[0076] Upon receiving user media from a mobile device 114, the BTS 112 encapsulates the natively-encoded media in a format suitable for transmission over the IP network 110. The BTS 112 acts under the direction of the SS 128 (not shown in FIG. 7) to route the encapsulated user media over the IP network 110 directly to the other endpoint of the session. For example, if the first 114A and second 114B mobile devices are on a session, the BTS 112A serving the first mobile device preferably routes the encapsulated media on a path 712 directly to the BTS 112B serving the second mobile device. The second BTS 112B, upon receiving the user media, preferably removes the encapsulation to obtain the natively-encoded data. The BTS 112B sends the user media to the mobile device 114B via the path 710B over the air interface.

[0077] Similarly, if the first mobile device 114A is on a session with a device on the PSTN 122 or PLMN 124, the BTS 112A preferably routes the user media on a path 714 to the media gateway 132 serving the PSTN and/or PLMN. The media gateway 132 extracts the user media from the encapsulation and, if necessary, converts the media into the native format of the network (i.e., PSTN 122 or PLMN 124) of the other device on the session. The media gateway 132 routes the converted user media on a path 716, 718 to the PSTN 122 or PLMN 124.

[0078] In sum, the telecommunications system 100 allows non-packet switched communications interfaces and protocols to be used over a packet switched network. Using the network in this way allows the media and control functionality of the system 100 to be distributed throughout the network in an efficient and cost-effective manner and eliminates the need for separate mobile switching centers and base station controllers.

[0079] The above description is included to illustrate the operation of the preferred embodiments and is not meant to limit the scope of the invention. The scope of the invention is to be limited only by the following claims. From the above discussion, many variations will be apparent to one skilled in the relevant art that would yet be encompassed by the spirit and scope of the invention.

## CLAIMS

We claim:

1. A telecommunications system for utilizing a packet switched network adapted to carry user media encapsulated in a packet-based representation to provide communications capabilities to mobile devices, the system comprising:
  - 5 a base transceiver station (BTS) in communication with the packet switched network and adapted to communicate with a mobile device, the BTS adapted to receive user media encoded in a representation native to the mobile device from the mobile device and encapsulate the user media in a packet-based representation for communication over the packet switched network; and
  - 10 a media gateway module in communication with the packet switched network and a telephone network, the media gateway adapted to receive the user media encapsulated in the packet-based representation and communicate the user media to the telephone network in an encoding native to the telephone
  - 15 network.
2. The system of claim 1, wherein the media gateway module is remote from the BTS.
3. The system of claim 1, wherein the telephone network is a public switched telephone network.
- 20 4. The system of claim 1, wherein the telephone network is a public land mobile network.
5. The system of claim 1, wherein the media gateway module comprises:
  - a network interface module adapted to convert user media between the native
  - 25 encoding of the mobile device and the native encoding of the telephone network.
6. The system of claim 1, further comprising:
  - a media control module adapted to create, maintain, and release communications
  - paths for routing the encapsulated user media across the packet switched
  - network.

7. The system of claim 6, wherein the media control module is further adapted to create a communication path routing the user media directly to an endpoint of a session.
8. The system of claim 1, further comprising:  
a softswitch module in communication with the packet switched network and  
5 adapted to provide media connection signaling for the mobile device via control signals carried over the packet switched network.
9. The system of claim 8, wherein the control signals are non-packet-based control signals encapsulated in a packet-based representation.
10. The system of claim 8, wherein the softswitch module comprises:  
a mobility management module adapted to provide mobility management for the  
10 mobile device via control signals carried over the packet switched network.
11. The system of claim 8, wherein the softswitch module comprises:  
a feature control module adapted to provide enhanced calling services to the mobile device via control signals carried over the packet switched network.
15. 12. The system of claim 8, wherein the softswitch module comprises:  
a session processing module adapted to set up, tear down, and account for sessions utilizing the mobile device via control signals carried over the packet switched network.
20. 13. The system of claim 1, wherein the BTS comprises:  
a signaling management module adapted to perform signaling management for the mobile device responsive to control signals received via the packet switched network.
25. 14. A method of utilizing a packet switched network adapted to carry user media encapsulated in a packet-based representation to provide communications capabilities to mobile devices, the method comprising:  
exchanging user media with a mobile device, the user media encoded in a representation native to the mobile device;

encapsulating the encoded user media in a packet-based representation adapted for communication via the packet switched network; and  
receiving the encapsulated user media and providing the user media to a telephone network, the provided user media encoded in a representation native to the  
5 telephone network.

15. The method of claim 14, wherein the telephone network is a public switched telephone network having a native representation of the user media different than the native representation of the mobile device.

16. The method of claim 14, wherein the telephone network is a public land mobile  
10 network.

17. The method of claim 14, wherein the providing step comprises the step of:  
converting the user media from the native encoding of the mobile device to the  
native encoding of the telephone network.

18. The method of claim 14, further comprising the step of:  
15 creating a communication path for routing the user media directly to an endpoint of a session via the packet switched network.

19. The method of claim 14, further comprising:  
providing media connection signaling for the mobile device via control signals  
carried over the packet switched network.

20. The method of claim 19, wherein the control signals are non-packet-based  
20 control signals encapsulated in a packet-based representation.

21. The method of claim 14, further comprising:  
providing mobility management for the mobile device via control signals carried  
over the packet switched network.

22. The method of claim 14, further comprising:  
25 providing enhanced calling services to the mobile device via control signals carried  
over the packet switched network.

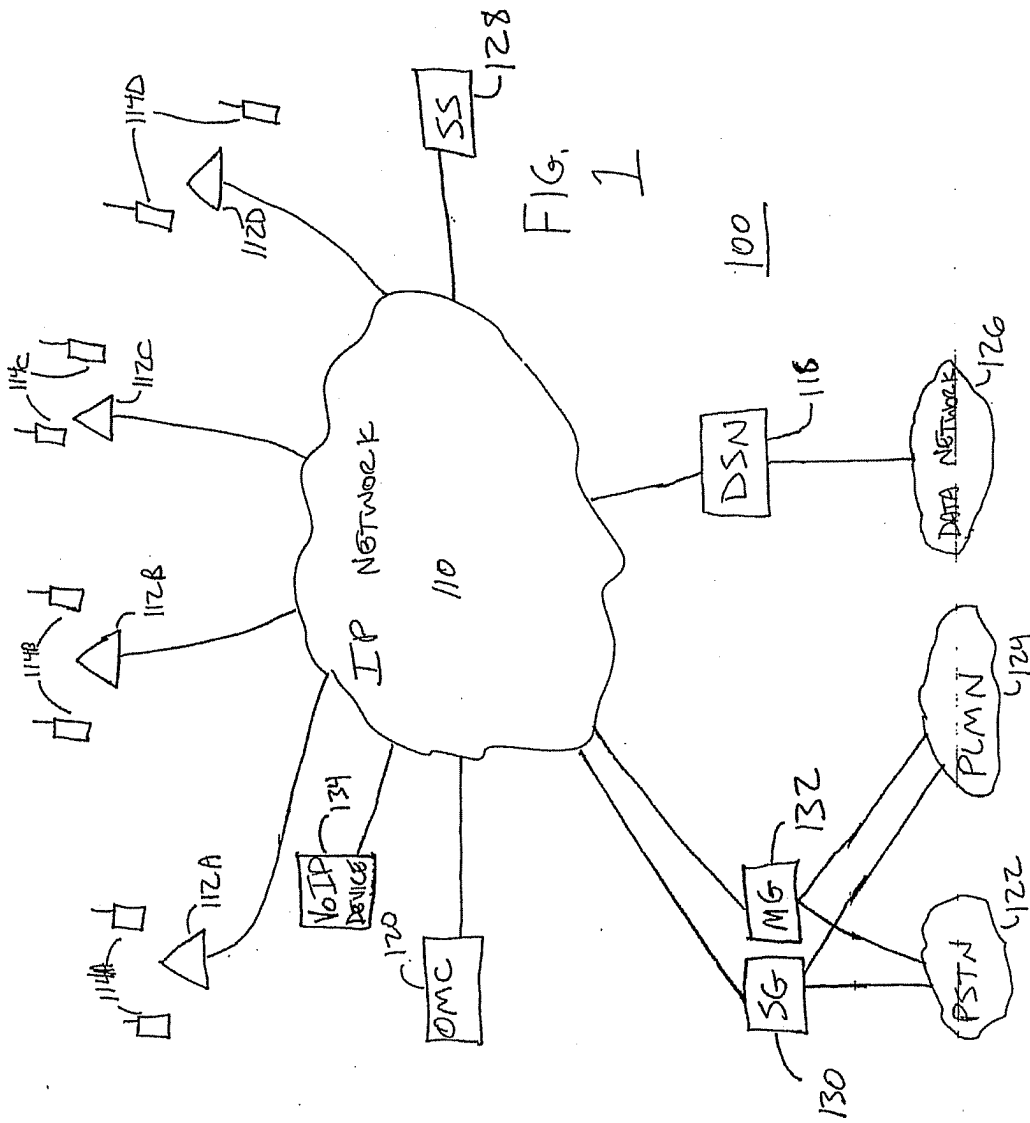
23. The method of claim 14, further comprising:  
setting up, tearing down, and accounting for sessions utilizing the mobile device via  
control signals carried over the packet switched network.
24. The method of claim 14, further comprising:  
5 providing signaling management for the mobile device responsive to control signals  
received via the packet switched network.
25. A base transceiver station (BTS) for interfacing with a packet switched network  
to provide communications capabilities to mobile devices, the BTS comprising:  
a communications module for exchanging user media with a mobile device, the user  
10 media encoded in a representation native to the mobile device;  
a signaling management module, coupled to the communications module, for  
managing messaging for the mobile device responsive to control signals  
received via the packet switched network; and  
a media control module for encapsulating the user media in a packet-based  
15 representation and for routing the encapsulated user media on a path over the  
packet switched network directly to an endpoint of a session responsive to  
control signals received via the packet switched network.
26. The BTS of claim 25, wherein the communications module further comprises:  
a radio for exchanging user media with the mobile device via an air interface.
- 20 27. The BTS of claim 25, wherein the control signals are received from a switch  
controller remote from the BTS.
28. The BTS of claim 25, wherein the endpoint for the session is at a media gateway  
remote from the BTS, the media gateway interfacing with a telephone network.
29. The BTS of claim 25, wherein the endpoint for the session is at a second BTS,  
25 the second BTS interfacing with a second mobile device.
30. A system for interfacing via a packet switched network with base transceiver  
stations (BTSs) in communication with mobile devices to provide communications capabilities  
to the mobile devices, the system comprising:

- a softswitch module for controlling media connection switching and signaling for the mobile devices via control signals encoded in a packet-based representation and transmitted to the BTSs via the packet switched network; and
- 5 a media gateway module interfacing with a telephone network and adapted to receive user media from the mobile devices via the packet switched network, the user media encoded in a representation native to a mobile device and encapsulated in a packet-based representation, the media gateway module further adapted to provide the user media to the telephone network encoded in a representation native to the telephone network.
- 10 31. The system of claim 30, wherein the media gateway module comprises:  
a network interface module adapted to convert user media between the native encoding of the mobile device and the native encoding of the telephone network.
- 15 32. The system of claim 30, further comprising  
a media control module adapted to create, maintain, and release communications paths for routing the encapsulated user media across the packet switched network.
33. The system of claim 32, wherein the media control module is adapted to create a communication path routing the user media directly to an endpoint of a session.
- 20 34. The system of claim 33, wherein the endpoint of the session is a BTS on the packet switched network.
35. The system of claim 33, wherein the endpoint of the session is at the media gateway module.
- 25 36. The system of claim 30, wherein the control signals are non-packet-based control signals encapsulated in a packet-based representation.
37. The system of claim 30, wherein the softswitch module comprises:  
a mobility management module adapted to provide mobility management for the mobile device via control signals carried over the packet switched network.



38. The system of claim 30, wherein the softswitch module comprises:  
a feature control module adapted to provide enhanced calling services to the mobile  
device via control signals carried over the packet switched network.
39. The system of claim 30, wherein the softswitch module comprises:  
a session processing module adapted to set up, tear down, and account for sessions  
utilizing the mobile device via control signals carried over the packet  
switched network.
- 5

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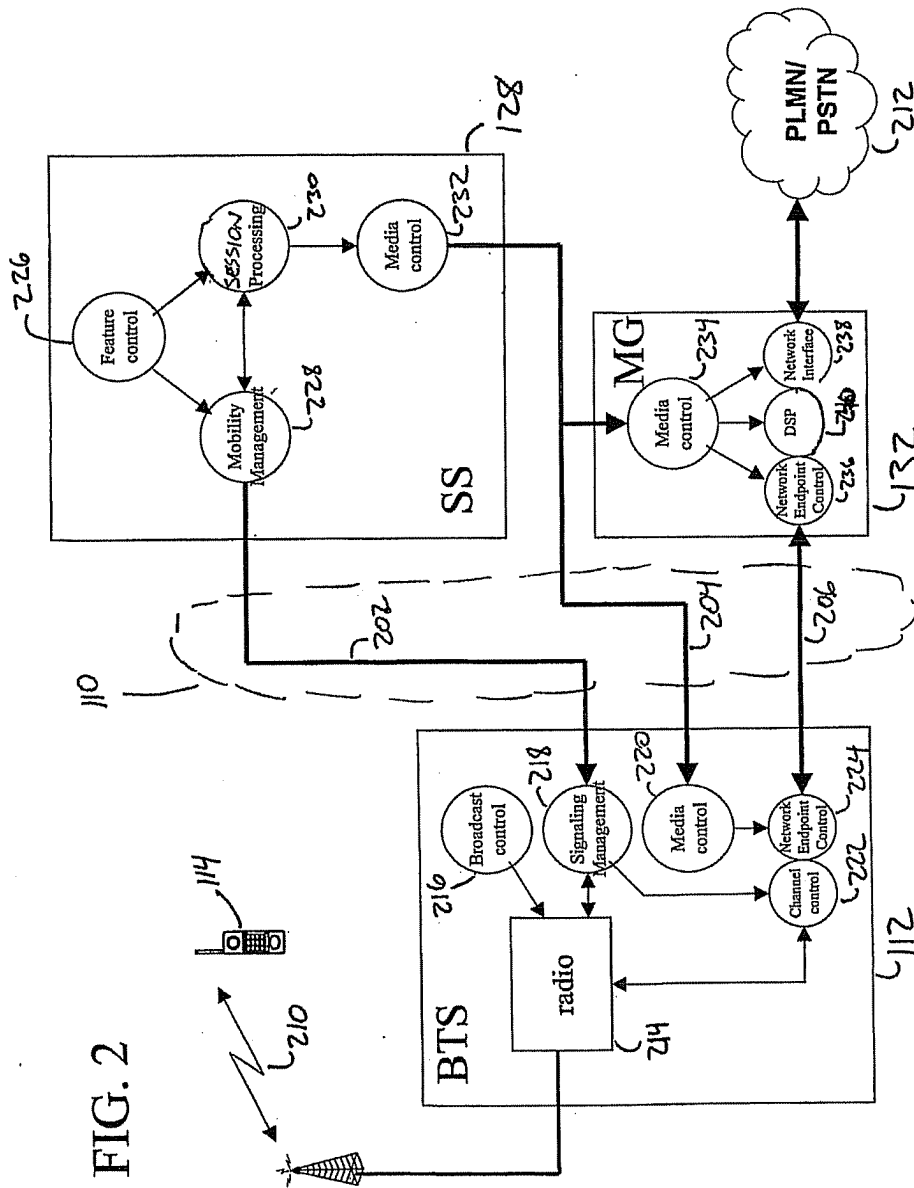


FIG. 2

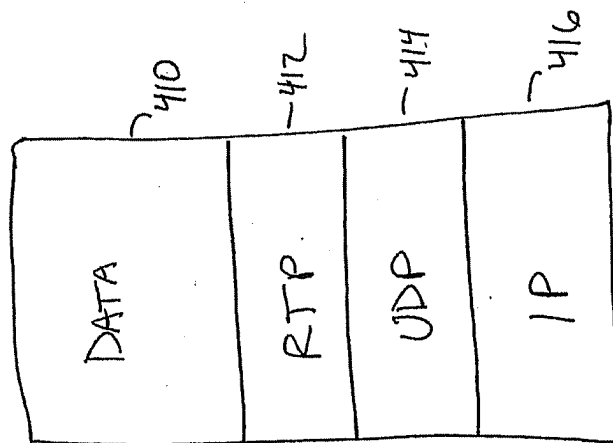


FIG. 4

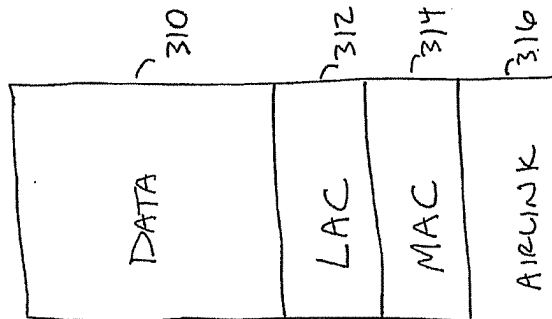


FIG. 3

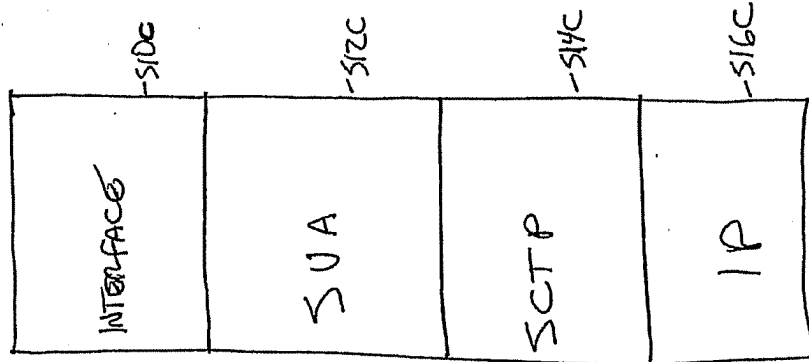


FIG. 5C

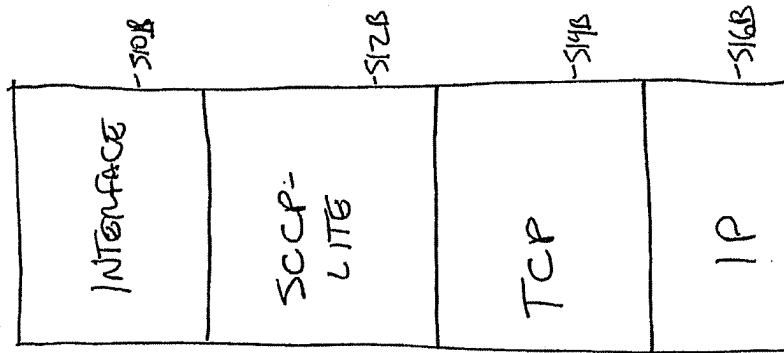


FIG. 5B

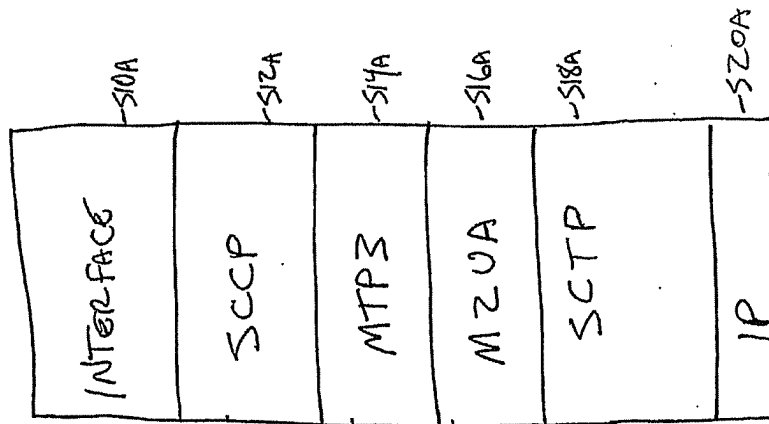


FIG. 5A

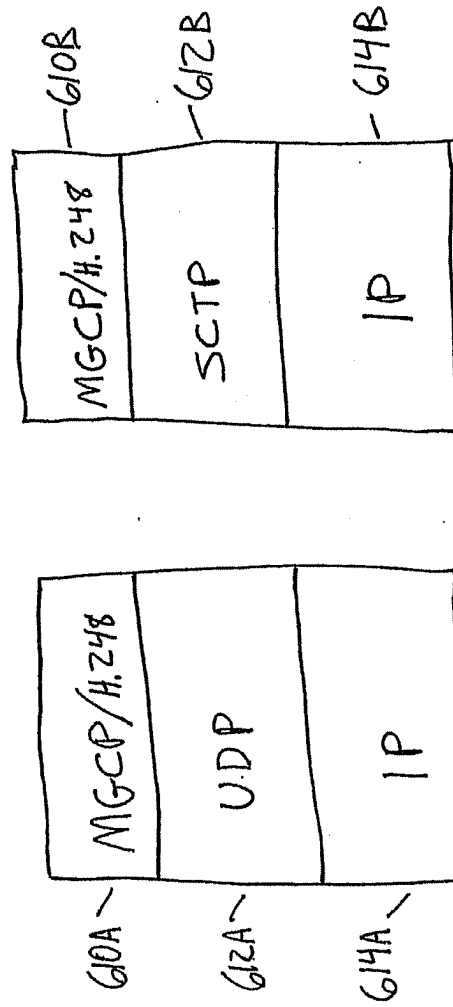


FIG. 6B

FIG. 6A

